

Table of Contents

U.S. Senate

Date: Wednesday, June 13, 2018

Committee on Environment
and Public Works

Washington, D.C.

STATEMENT OF:

PAGE:

THE HONORABLE JOHN BARRASSO, A UNITED STATES SENATOR FROM THE STATE OF WYOMING	3
WILLIAM "BILL" PANOS, DIRECTOR, WYOMING DEPARTMENT OF TRANSPORTATION	7
SHAILEN BHATT, PRESIDENT AND CEO, INTELLIGENT TRANSPORTATION SOCIETY OF AMERICA	12
ZACHARY DOERZAPH, DIRECTOR, CENTER FOR ADVANCED AUTOMOTIVE RESEARCH	18
POLLY TROTTEBERG, COMMISSIONER, NEW YORK CITY DEPARTMENT OF TRANSPORTATION	23
SHAUN KILDARE, DIRECTOR OF RESEARCH, ADVOCATES FOR HIGHWAY AND AUTO SAFETY	29
THE HONORABLE THOMAS CARPER, A UNITED STATES SENATOR FROM THE STATE OF DELAWARE	44

HEARING ON INNOVATION AND AMERICA'S INFRASTRUCTURE: EXAMINING
THE EFFECTS OF EMERGING AUTONOMOUS TECHNOLOGIES ON AMERICA'S
ROADS AND BRIDGES

Wednesday, June 13, 2018

United States Senate

Committee on Environment and Public Works

Washington, D.C.

The committee met, pursuant to notice, at 10:06 a.m. in room 406, Dirksen Senate Office Building, the Honorable John Barrasso [chairman of the committee] presiding.

Present: Senators Barrasso, Carper, Capito, Wicker, Fischer, Rounds, Ernst, Sullivan, Cardin, Merkley, Gillibrand, Booker, Markey, and Van Hollen.

STATEMENT OF THE HONORABLE JOHN BARRASSO, A UNITED STATES
SENATOR FROM THE STATE OF WYOMING

Senator Barrasso. Well, good morning. I call this hearing to order.

Today we are going to examine the implications of emerging technologies of America's roadway infrastructure.

Last month, our Committee unanimously passed bipartisan legislation to approve America's water infrastructure. We are now working together to pass America's water infrastructure act on the Senate Floor. I believe this bipartisan success on water infrastructure is going to lead to bipartisan success on America's surface transportation infrastructure, namely, legislation to address our roads and our bridges.

We are planning to build infrastructure that will last for decades. We need to understand the new challenges that those decades will bring to all of us. The ongoing development and implementation of autonomous vehicles and connected vehicles and other innovations have the potential to fundamentally change the way our Nation's infrastructure works.

Autonomous vehicles will likely require modification to our roadways and changes to the practices of Federal, State, and local transportation agencies. It is critical that State and Federal transportation agencies are prepared and equipped to tackle the potential opportunities and challenges they present

for our roads. Those agencies will need to develop, install, and maintain traffic control devices in such a way that they are understood and obeyed by motorists, as well as autonomous vehicles.

As autonomous vehicles become more common on the road, they could influence regional traffic models and forecasts. They will also add new factors as agencies make long-term planning decisions. At the same time, new vehicles technologies offer many potential benefits and could transform the way that we view surface transportation altogether.

Soon, elderly and disabled Americans, as well as those without a car of their own, may be able to travel by vehicle with greater ease and greater independence. Likewise, these innovations have great potential to reduce crashes and fatalities, to improve mobility, and to increase the efficiency of the roadway system. How their benefits are realized will depend on industry and agencies working together to make sure that our roads keep pace with the vehicles that they accommodate.

An excellent example of infrastructure innovation is happening in my home State of Wyoming. The Wyoming Department of Transportation is implementing a Connected Vehicle Pilot program to improve to improve monitoring and reporting of road conditions on Interstate 80. Projects like these are vital for

the future of our Nation's roadway infrastructure.

So, I am glad that Bill Panos, the Wyoming Director of the Department of Transportation, is here to tell us more about that project and other work being done in his department.

I also want to thank all of the other witnesses for participating in today's hearing. Your expertise and insight will help us understand potential high-tech challenges and opportunities for our Nation's roadway infrastructure.

Senator Carper is unavoidably delayed; he will be here shortly, and he will make his full opening statement at that time.

So, I want to thank all of you for being here.

I am pleased to welcome Bill Panos, who has served as the Director of the Wyoming Department of Transportation. He is a graduate of California State University, where he received a degree in forensic science and technology. Before moving to Wyoming, he accrued 37 years of experience leading private and public service organizations. He has also served as the Director of the Wyoming School Facilities Department.

Joining Bill today in testifying will be Mr. Shailen Bhatt, who is the President and CEO of the Intelligent Transportation Society of America; Mr. Zachary Doerzaph, who is the Director of the Center for Advanced Automotive Research; Polly Trottenberg, who is the Commissioner for the New York City Department of

Transportation; and Shaun Kildare, the Director of Research at Advocates for Highway and Auto Safety.

I want to remind the witnesses that your full written testimony will be made part of the official hearing record today, so please keep your statements to five minutes so that we will have time for questions. I look forward to hearing the testimony from each of you.

With that, we will begin with Mr. Panos. Appreciate your being here.

[The prepared statement of Senator Barrasso follows:]

STATEMENT OF WILLIAM "BILL" PANOS, DIRECTOR, WYOMING DEPARTMENT
OF TRANSPORTATION

Mr. Panos. Chairman Barrasso and members of the Committee, I am Bill Panos, Director of the Wyoming Department of Transportation. I am here today on behalf of WYDOT and AASHTO.

The Committee's premise in holding this hearing is correct, connected and automated vehicles have implications for highway infrastructure. In addressing those infrastructure issues, safety is a top priority for State DOTs. That includes attention to striping and signage, as well as to more complex issues. Collaboration between technology developers, vehicle manufacturers, and government agencies is important. This includes working to ensure interoperability of systems so that deployment of dedicated short-range communications, or DSRC, along the highway system will be effective. Let me elaborate.

These new technologies have the potential to reduce crashes, save lives, and provide other benefits. However, there is still uncertainty surrounding these innovative technologies, including infrastructure-related issues. For example, for there to be highway infrastructure, work zones on the roads are inevitable. How will an automated driving system, or ADS, get by work zones? What are the specific signage and striping needs? What advisories from DSRC-enabled infrastructure would help connected and autonomous vehicles and improve safety?

State DOTs are preparing for deployment of CAVs by, among other things, starting to plan and deploy relevant technology as part of the highway infrastructure, and these investment needs are near-term, in part because a connected vehicle need not be an automated vehicle. Cars driven by people are increasingly equipped with electronics that can receive data from DSRC-enabled equipment along the roadway. DSRC signals can help non-automated, as well as automated, vehicles effectively “see” in bad weather, provide other information, such as on-traffic congestion.

State and local agencies are active in deploying and testing these systems today. Approximately 50 U.S. locations are deploying connected vehicle technologies. This represents roughly 72,000 vehicles and 65,000 devices installed on the Nation’s infrastructure. WYDOT is an active participant.

To improve safety along the 402 miles of Interstate 80 in Wyoming, particularly in our tough winters, Wyoming is implementing a pilot program using DSRC-enabled technology to connect vehicles to infrastructure and to other vehicles. During Federal fiscal year 2016, more than 1,600 crashes occurred on I-80 in Wyoming, resulting in 18 fatalities and 271 injuries. In December of 2016, there were only eight days when I-80 in Wyoming was fully open.

As part of the effort to improve the situation, the pilot

program will test warnings advising travelers of crashes ahead. It will also advise about weather, speed restrictions, work zones, and other matters. Testing with WYDOT vehicles occurred last winter, and we will be testing commercial freight vehicles this winter.

Let me turn to a few more points on the infrastructure implications of CAV deployment.

Currently, State DOTs are unsure which roadway elements are critically important to automated driving system, or ADS, technology. We know that quality signage and striping are important, but welcome more details. In most cases, striping is a maintenance, not a capital, activity. Similarly, sign maintenance is not a capital activity.

All other things being equal, an increase in maintenance costs would reduce funding available for capital investments in transportation, so we want to understand the maintenance implications of CAV deployment. In addition, if ADS-equipped vehicles have sensors that could be adversely impacted by poor ride quality, that could place upward pressure on already high needs for investments to maintain and improve pavement ride quality.

There are additional issues where State DOTs want to better understand what type of information would help all CAVs.

Deployment of ADS technology in rural environments also

raises issues. For example, DSRC-enabled infrastructure on long rural highways would be costly. This suggests different solutions for advisories in very rural areas, such as cellular technology, at least where there is adequate cell phone service. In any event, we want vehicles to have access to weather, crash, and other key advisory information. It seems that we have to put technology into the infrastructure to do that.

So, when a State DOT talks about interoperability, it is not to tell a developer how to equip a vehicle. Simply, if a State is deciding whether to use scarce infrastructure dollars to deploy DSRC-enabled systems, it wants to know that the investment in DRC can successfully communicate advisory information to vehicles.

In conclusion, Mr. Chairman, CAVs are arriving and are in our future. We want the infrastructure to be safer than it has ever been when they are deployed. States are eager to work hard towards those ends.

Thanks for the opportunity to appear before the Committee today.

[The prepared statement of Mr. Panos follows:]

Senator Barrasso. Thanks for your testimony, Mr. Panos.
Appreciate it.

Mr. Bhatt.

STATEMENT OF SHAILEN BHATT, PRESIDENT AND CEO, INTELLIGENT
TRANSPORTATION SOCIETY OF AMERICA

Mr. Bhatt. Chairman Barrasso, Ranking Member Carper, and members of the Committee, thank you for the opportunity to be here today. When last I testified in front of this Committee, I served as the Executive Director of the Colorado Department of Transportation. At that time, I discussed how a mix of road investment and innovation was needed to solve Colorado's 21st century transportation challenges.

I am now President and CEO of the Intelligent Transportation Society of America, which brings together public sector agencies, private sector companies, and researchers unified by our vision of a better world transformed by intelligent mobility, one that is safer, greener, and smarter. I am honored to be on this panel today with three ITS America members.

Today's hearing takes place at an important time. Just as infrastructure was critical to the development of our economy in the 20th century, maintenance of existing roads, bridges, and other infrastructure, and deployment of intelligent infrastructure will be critical for our global competitiveness in this century.

Advances in robotics, artificial intelligence, and wireless communications have inspired a race to make the next generation

of mobility a reality. We are on the leading edge of a technology revolution that will define the way people, goods, and information move in the 21st century. It is a whirlwind of innovation that will change entire industries, as well as transform communities large and small, urban and rural.

That transformation will positively affect both the safety and operation of our transportation system if we do it well. In 2016, 37,461 people died on U.S. roads. That is more than 100 people per day. Pedestrian deaths in that year rose 9 percent. More than 90 percent of roadway crashes are caused in some way by human error. That is a sobering statistic, but we have technologies that will make a difference.

Technologies such as pedestrian automatic emergency braking will use automation to detect pedestrians and prevent tragedies. Through dedicated short-range communications and other technologies, we also have the capability to allow vehicles to communicate with other vehicles, smart infrastructure, and other users of the system.

Safety has always been our top priority and is the reason many of us are passionate about this work.

In addition to injuries and fatalities, however, there are major mobility and environmental implications. Americans currently lose roughly 40 hours per person per year sitting in traffic, which costs each driver almost \$1,500 per year.

Collectively, this drains \$305 billion from our economy and wastes 3.1 billion gallons of fuel. Here, technology can play a key role in putting money back into Americans' pockets and improving the environment in which we live. Freight that is stuck in traffic costs Americans more.

This is why, under Colorado's RoadX program in 2016, we sent a truck on the world's first autonomous freight delivery. One of our members, Peloton, is developing driver-assisted truck platooning technology that will improve the flow of goods across the Country, while reducing fuel consumption of trucks by 7 percent.

Another way of reducing fuel consumption is through electrification, which is an important part of the future of intelligent mobility. Right now, by reducing crashes, we can greatly reduce traffic congestion in this Country. More than 50 percent of congestion is caused by non-recurring incidents. Minor fender-benders result in hours of frustration and inefficiencies in our system. The deployment of connected vehicle technologies will improve traffic flow across the Country.

Connected and automated vehicle technologies and smart infrastructure have the potential to give us back our most precious resource, time. By applying intelligent transportation technologies toward existing infrastructure, we can maximize the

efficiency of our system.

Twenty-six States and 45 cities are currently deploying V2I communications that use DSRC. Some of these applications will include bridge and pavement monitoring, curb speed warning, reduce speed areas such as in construction zone, and spot weather warnings, all of which will reduce crashes by providing vehicles and drivers with the most accurate and up-to-date information.

The most important connection between vehicles and infrastructure has historically been the tire. Today there are many ways for vehicles to interface with infrastructure and with other vehicles. We need to prepare for a future that involves a mixed fleet of intelligent and unconnected vehicles. The best way to do this is to maintain our infrastructure in a state of good repair, specifically as that relates to pavement markings and signage.

However, we need to understand signs that work well for human eyes may need to be adapted for machine reading. We also need to understand how cities and States will take these waves of big data that vehicles are producing and turn it into actionable information.

Before I close, I urge Congress and the Administration to identify long-term sustainable funding for the Highway Trust Fund to maintain our infrastructure for all the reasons I have

just outlined. In my nearly 10 years as a State DOT leader, I have always said that Departments of Transportation exist to save lives and make people's lives better. I firmly believe that advances in vehicle technology and in smart infrastructure are the best tools in our toolbox to achieve those goals.

Thank you again for this opportunity, and I am happy to answer your questions.

[The prepared statement of Mr. Bhatt follows:]

Senator Barrasso. Thank you very much, Mr. Bhatt. We appreciate your being here.

Mr. Doerzaph.

STATEMENT OF ZACHARY DOERZAPH, DIRECTOR, CENTER FOR ADVANCED
AUTOMOTIVE RESEARCH

Mr. Doerzaph. Chairman Barrasso and members of the Senate Committee on Environment and Public Works, at BTTI we conduct research for many public and private organizations on automated systems that are infrastructure and the people who own, operate, and ride within them. It is an honor to be here to discuss this very important topic with you. I am quite passionate about it myself.

Automation may indeed substantially one day have a positive impact on transportation safety and efficiency. However, exceeding the capability of the human driver is extraordinarily difficult and is currently underestimated by many. To achieve the same safety benefit as the best 10 percent of drivers, automated vehicles, for all practical purposes, can never virtually crash.

Large-scale deployment of automated vehicles will take decades to achieve, and there will be a significant percentage of manually driven vehicles for the foreseeable future. Automation remains costly, does not equally benefit all users, and does not operate ubiquitously across all environments.

Fortunately, though, automated vehicles are very much being designed to operate on roadways that were created for human drivers. As with humans, the reliability of those automated

systems depends on things like roadway design quality, lane markings, signs, and other traffic control devices.

At the same time, though, specific infrastructure elements do create particular challenges unique to automated vehicles. These edge-and-corner cases, as we call them, pertain to things like work zones and emergency situations, adverse weather, and anywhere that humans can exchange a simple nod, glance, or hand wave in order to communicate with another road user, which is where connected vehicle technologies come in. These technologies which allow vehicles to communicate with other vehicles, as well as the infrastructure and other road users, provide an additional mechanism for improving the perception, recognition, path planning processes for automation, resulting in safer and more efficient systems overall.

Connectivity also enables this proactive conversation to take place between vehicles and vehicles in infrastructure, much like humans do today.

So, in conclusion, I believe there are measured actions that should be taken by all stakeholders based on careful planning to exercise that safety is maintained throughout the evolution and deployment of automated vehicles, and I recommend doing so through the following approach.

Support partial automation today. These are systems which are compatible with the infrastructure and, when appropriately

designed, these limited automations, such as emergency automated braking, lane-keep assist, and others, improve safety and reduce congestion by leveraging the strengths of both the human and the machine.

The Federal Government can play a role in providing a clear pathway to increasing levels of automation with appropriate operational domains based on demonstrated success.

I also believe we need to incentivize precompetitive collaboration between individual companies, as well as between those companies and the road operators, to collaboratively overcome the technology and policy hurdles.

We also need to facilitate the mechanisms for automated vehicles to report road deficiencies back to the operators so that we have a closed-loop cycle of improving those facilities. We need to provide the resources and guidance required to improve our physical and digital infrastructure through applied research and deployment support.

Connected technologies require a robust, nationally interoperable back-end data system, precise vehicle localization, and accurate infrastructure information across city, State, and local borders. It is imperative that security mechanisms which establish digital trust and identify and remediate threats are in place.

We also need to facilitate a broad dialogue and correlation

to define the appropriate oversight role for the Federal and State public agencies to develop mechanisms for monitoring and updating such oversight in order to balance innovation with public safety based on objective measures.

And, finally, I would be remiss if I did not mention that I believe we need to maintain this pace of innovation by facilitating next generation transportation workforce through technology-focused multidisciplinary education and by supporting a variety of programs for students at all levels.

[The prepared statement of Mr. Doerzaph follows:]

Senator Barrasso. Well, thanks so much for your testimony. It will be interesting about this next generation workforce. I look forward to getting into that with the questioning.

Commissioner Trottenberg, thank you very much for joining us. Please proceed.

STATEMENT OF POLLY TROTTEBERG, COMMISSIONER, NEW YORK CITY
DEPARTMENT OF TRANSPORTATION

Ms. Trottenberg. Thank you.

Good morning, Chairman Barrasso and members of the Committee. On behalf of Mayor Bill de Blasio, I thank you for inviting me here today to share New York City's perspective on the deployment of highly automated vehicles in major urban areas.

New York, like our sister cities, shares a common interest in ensuring HAV technology is deployed in a way that enhances urban mobility, safety, and environmental sustainability. We are grateful to have this opportunity to discuss areas of concern and see where there are areas of partnership.

As the Nation's largest and densest city, with a population of 8.6 million and growing, New York City is responsible for the operation and maintenance of a highly complex surface transportation network, including 6,000 miles of heavily traveled urban roadways, 12,000 miles of sidewalks, over 13,000 signals, and nearly 800 bridges and tunnels, many of them well over 100 years old; and we work closely to operate an integrated and efficient transportation system with the MTA, which runs our subway and bus system with over 8 million transit trips per day.

I hope my perspective as a city DOT commissioner and former undersecretary at USDOT will prove useful as the Senate

deliberates on the opportunities and challenges we face with HAVs and the implication of this technology for our roads and bridges.

Comments from industry suggest that cities need to get their infrastructure ready for the deployment of HAVs. I would argue just the opposite.

New HAV technology should, instead, be prepared to operate safely and effectively in complex urban environments; in snow, with traffic control officers managing an intersection when signals are out and judgment is needed; or where pavement conditions or lane markings are deteriorated. It is simply not realistic or feasible to expect cities to overhaul their existing roadway infrastructure to accommodate a still somewhat unproven technology.

New York is proud to be the first U.S. city to embrace the concept of Vision Zero, which declares that all traffic deaths and serious injuries are preventable. In the last four years, New York City has achieved remarkable results. Traffic deaths have declined by 27 percent and pedestrian fatalities have declined by 44 percent. And New York City is bucking the national trend, where, tragically, roadway fatalities have increased by 15 percent.

We have achieved these results through a strong partnership between New York City DOT and the NYPD, as well as robust

investment in a comprehensive data driven roadway safety program relying on engineering, education, and enforcement. HAVs hold the promise of dramatically reducing traffic deaths and serious injuries, but, to achieve this promise, the U.S. should first establish rigorous foundational safety standards across the board.

For example, the European Commission recently proposed that, starting in 2020, all new vehicles sold in Europe must be equipped with intelligent speed assistance, pedestrian and cycling recognition systems, and automated braking.

In the U.S., we should be advancing similar standards and NHTSA should build on and integrate the best elements of the approaches being used by California and Boston, adopting an approach of incremental testing for HAVs with data sharing requirements.

Cities are where the bulk of Americans live and travel now, and for many, including New York, congestion has become a critical challenge. HAVs hold the promise of reducing congestion or profoundly exacerbating it. Unfortunately, to date, the Federal Government has not meaningfully involved cities in its development of HAV policy. Moving forward, we request that USDOT and NHTSA engage with cities more directly. We will all be most successful as partners, cities, States, USDOT, and the industry.

It is critical to establish protocols that allow HAV safety data to be shared with States and cities. Some data, when appropriate, should also be shared publicly. Providing for a robust level of transparency for HAV safety data will be essential to create a safety culture akin to that of the U.S. aviation sector.

Throughout U.S. history, traffic safety has always been a shared responsibility of the Federal, State, and local governments. This authority must be unambiguously preserved in the AV START Act, and HAVs must be programmed to follow all State and local laws, including speed limits.

The legislation also does not require standards-based verifiable testing of HAV systems. We urge the Senate to revise the legislation before it advances.

Of all the disruptive challenges HAVs are poised to bring, none may be as consequential as the impact on our Nation's workforce. According to recent census data, more than 4.4 million Americans, including approximately 250,000 New Yorkers, make their living driving.

All of our communities, urban and rural alike, will need to confront the potential human toll that this disruptive technology could take. The Federal Government needs to help ensure that innovation and opportunity for some does not mean we are leaving others without a livelihood.

As Congress considers its approach to fast developing HAV technology, I urge you to enlist cities as partners. New York City stands ready to work with you.

I thank the Committee and look forward to your questions.

[The prepared statement of Ms. Trottenberg follows:]

Senator Barrasso. Thank you so much for your testimony,
Commissioner Trottenberg.

Mr. Kildare.

STATEMENT OF SHAUN KILDARE, DIRECTOR OF RESEARCH, ADVOCATES FOR
HIGHWAY AND AUTO SAFETY

Mr. Kildare. Good morning, Chairman Barrasso, Ranking Member Carper, and members of the Committee. I am Shaun Kildare, Director of Research for Advocates for Highway and Auto Safety, a coalition of public health, safety, consumer organizations, and property casualty insurance companies dedicated to advancing safer vehicles, safer drivers, and safer roads. Thank you for the opportunity to testify.

Each year motor vehicle crashes kill tens of thousands of people and injure millions more, at a cost of over \$800 billion. Moreover, at a time when deaths on our Nation's roads are remaining unacceptably high, America's infrastructure is in deep disrepair. The American Society of Civil Engineering gives our roads a grade of D and reports that 1 in 11 of our nearly 615,000 bridges are structurally deficient.

In addition to committing resources to fix our roads and bridges, substantial investments will be required to ensure that autonomous vehicles, or AVs, can operate safely. Federal leadership is needed to achieve infrastructure improvements and to create a regulatory framework for vehicle design and performance.

Advocates has always been a strong champion for vehicle safety technology and infrastructure improvements. So too do we

believe that in the long-term AVs may once and for all bring about meaningful reductions in the death and injury toll on our Nation's roads. The industry touts that AVs will improve safety, reduce congestion, and benefit the environment. Instead, what we have seen is a number of crashes resulting in at least three deaths.

At the time of the fatal pedestrian crash in Arizona, Uber had logged approximately 3 million autonomous miles. While that may sound like a large number, consider that every year Americans drive 3 trillion miles. During those 3 trillion miles, on average, a person was killed in a traffic collision every 85 million miles in 2016. In comparison, Uber's AV fatality rate is 28 times that of human drivers. This highlights just how little proof there is that these systems are safe or certainly not safer than human drivers presently.

Statements regarding reductions in congestion and improvements in the environment are similarly dubious. There is a wide variation regarding estimates of changes in vehicle miles traveled. Often absent from these urban planning utopias is the reality that AVs may bring the possibility of hypercommuters living several hours outside of cities. Also frequently missing is the likelihood of empty vehicles circling aimlessly between rides.

What we do know is that after the March 23rd Tesla crash in

California, U.S. Highway 101 was closed for nearly six hours. The battery was on fire, emitting dangerous chemicals, and the battery reignited five days afterwards. That paints a very grim picture.

The fact is that rushing to deploy AVs provides no guaranty of the benefits claimed and may come with significant costs. Despite these uncertainties, the USDOT has chosen to take a hands-off approach by issuing only voluntary guidelines. Therefore, Advocates has put forth several reasonable proposals which are outlined in my written testimony.

Regarding infrastructure improvements, we offer the following three recommendations:

First, for road design. The lynchpin for much of the guidance in numerous infrastructure manuals is a human behind the wheel. From sight distances for signs, to lettering, to the curvature and super elevations of roads, infrastructure design criteria has been developed to enable a safe operation of vehicles by human drivers. AVs may require that these basic premises be modified in order to serve a dual purpose for both human- and computer-driven vehicles.

Second, roadway deterioration. We have all experienced road signs or markings that have been damaged intentionally or altered or blocked by objects. Research shows that a stop sign can easily be manipulated with a few pieces of tape, which is

then read by the AV to be a 45 mile an hour speed limit sign, resulting in the AV speeding up instead of stopping. This is why Advocates is recommending AVs be subject to a vision test. When a person goes to a DMV to get a license, he or she has to take a vision test. With the AV now being the entity that is seeing the road, AVs should have to demonstrate that they can see and respond to the roadway challenges.

Third, connected vehicles. These technologies allow a vehicle to send and receive communications with other vehicles, known as V2V, or the infrastructure, known as V2I. They will likely help fill gaps in AV performance. For example, V2V communication can provide safety applications for Forward Collision Warnings which alert drivers to stopped or slowed vehicles ahead. Advocates has filed comments in support of mandating V2V; however, the rule continues to languish at USDOT.

To conclude, this hearing is very well timed, considering that last week the NTSB released their preliminary report on the fatal Tesla crash in California this March. It appears likely that infrastructure components may have been a factor in that crash. As such, we urge the Senate to allow time for the NTSB to finish its pending investigations on AV systems. There is a great deal to be learned from our Nation's leading investigators, and there is no reason to rush through legislation, especially by tacking it on to an unrelated bill.

I look forward to your questions.

[The prepared statement of Mr. Kildare follows:]

Senator Barrasso. Thanks so much to all of you for being here. I look forward to starting the questions in a second.

I do, first, ask unanimous consent to enter into the record a letter from the Alliance of Automobile Manufacturers, which explains the benefit of a development in eventual deployment of autonomous vehicles. Without objection, that will be submitted.

[The referenced information follows:]

Senator Barrasso. Mr. Panos, as you discussed in your testimony, the Wyoming Department of Transportation is participating in the U.S. Department of Transportation study to assess the effectiveness of connected vehicle technologies really under real-world conditions, because that is what this is all about. How has this effort helped WYDOT anticipate the changes that are going to be needed so that we can get the greatest benefit from connected vehicles and AV implementation?

Mr. Panos. For us, the participation with USDOT and with our partners on the project is really a benefit to us because our focus is on safety, and the idea that we have the ability to deploy technology in a variety of different environments. As you know, the pilot study is not just about Wyoming, but it is also inclusive of New York City, the New York area, and also Florida; and working in these kinds of deployments and these kinds of environments is extremely beneficial to studying the effectiveness of the technology and the various conditions within which it is going to have to operate, so that is very, very important.

As I described both in my written and oral testimony, we have already started to deploy not only the technology within our own fleet, but with freight vehicles as we move forward, so I think that the ongoing funding by USDOT, ongoing funding by the Federal Highway Administration towards going to Phase 2,

Phase 3, towards further deployment of these technologies is critical for us to improve safety.

In our particular case, we have a great deal of freight that moves through the southern part of our State, and our focus is on not only maintaining a safe environment for that freight to move, fewer fatalities, fewer crashes, et cetera, but fewer closures of that road system so that freight can move from the western side of the Country to the eastern side of the Country and vice-versa.

So, for us, these connected vehicle programs are an initial step towards connected braking and then automated vehicle programs which are necessary to save lives.

Senator Barrasso. In addition to the study that you are actually involved in, are there any further efforts or follow-up activities that we ought to be thinking about or pursuing to get more information?

Mr. Panos. Yes. I think that FHWA recently announced a series of national meetings to discuss automated vehicles and infrastructure. Congress can encourage the FHWA to move forward promptly on those meetings.

AASHTO has been working hard to bring people together for years and has updated its coalition of public and private sector entities to form the Cooperative Automated Transportation Coalition, or CAT Coalition. Those types of efforts should be

encouraged. They will help bridge some of the current gaps in the collaboration among all of the various stakeholders.

Senator Barrasso. Mr. Bhatt, everybody has testified to this. In order to successfully prepare our roadways for autonomous vehicles, State and Federal agencies are going to need to engage in proactive preparation, rather than just simply reacting. What do you perceive as kind of the primary regulatory challenges or opportunities that are going to determine the infrastructure and agency readiness as the use is adopted and expanded for autonomous vehicles?

Mr. Bhatt. Thank you, Chairman, for that question. It is a great question to ask right now because I think that what you hear in the testimony across this panel is there is both great opportunity and great challenges that we need to understand, and I think it is a great time for this Committee, Congress as a whole, and the Administration to be looking at these issues.

From a regulatory standpoint, I think what we need right now is a Federal framework so that we don't have 50 different States and then along with other cities and jurisdictions sort of developing their own standards when it comes to the operation of these vehicles. I think that that is one of the things that we are looking for.

I also think it would be important for us to recognize that this is not just about the United States; that there is a global

competition around both vehicle manufacturing and communication technologies where other Countries are investing and actually cite the fact that there is no consistency across the United States as a competitive advantage for companies to come and manufacture and test in those places.

So, I think that what we want to make sure is that we preserve the historic, that we have had for several decades, relationship of manufacturers make the vehicles and then local jurisdictions decide how they are operated, but we need a Federal framework to make that happen.

Senator Barrasso. Thank you very much.

I have a lot more questions, but, Senator Rounds, let me go to you first.

Senator Rounds. Thank you, Mr. Chairman. As I listened to the discussion here, I noted that we have folks from New York, Wyoming, Colorado, and when I think about the differences between the way each of your different transportation commissions would respond to what your needs are, and I am not certain that, at the Federal level, we can determine for all of them what they need to do and the priority in which they need to do it.

At the same time, I guess I am going to ask the loaded question, and that is with regard to the Highway Trust Fund. Is there anybody that thinks that we should have a subsection

dedicated to the advancements of these particular capabilities within the Highway Trust Fund? Remembering that you are probably taking money away from bridges and road repair, road construction and so forth. Where do you put this at? Yes, sir.

Mr. Bhatt. I am happy to take the loaded question, and I appreciate your perspective that it is a very different Country, whether it is New York City or Wyoming, Colorado or Washington, D.C. And I appreciate the idea that we recognize that.

I think that from the ITS America perspective, which is a coalition of State DOTs, cities, private sector companies, and research institutions, I think, with regard to the Highway Trust Fund, recognizing the challenges that are there, it is hard to say, well, how do you fund important technology investments and, at the same time, many States are struggling with this idea of we can't maintain the existing roads and bridges that we have.

So, I would say that our association would say, along with, I think, a broad bipartisan chorus, that there does need to be more funding available for transportation, but I think that what I would focus on is the ability of technology to leverage existing investments.

We all talked about pavement markings. Striping is a big deal obviously for the performance of autonomous vehicles. In Colorado we had the Eisenhower-Johnson Tunnel, the highest interstate tunnel in the Country, and snow can fall there

virtually any time of the year. Those plows go out, and a stripe is just really paint on asphalt. You plow it enough times, it comes off. What they have deployed in Colorado now is almost like a recess within an LED light inside it, so when that plow goes over it, it doesn't scrape away paint, it doesn't scrape away anything, and it is a much safer piece of infrastructure.

And the next step of technology is, I have talked to companies that want to put a little RFID chip in there so that that RFID chip can broadcast to a plow that I am here, so if you can't see the roadway, that you at least understand where the lane is.

So, whether it is signals through the SPaT Challenge that can be upgraded, I think that there are many ways that we can see that technology can leverage the existing investment. We currently use 2,000 vehicles per lane per hour for what a lane of interstate will move. Once those vehicles are talking to each other, you can cut down on stopping distance. I have seen estimates where that can go to 4,000 or even higher. So, I think we want to begin the conversation around how do we use investment to leverage both the existing infrastructure and the technology investment.

Senator Rounds. Interesting. I am just curious. I look at the different weather conditions that are out there right now

and my first thought was is perhaps the first step would be to provide more information to both drivers and driverless vehicles, and a lot of that data could be used by both, as opposed to simply focusing on the autonomous vehicles.

You mentioned snow. I am thinking of the percentage of the time in which our rural highways and places like in South Dakota, where I am from, where we are not going to have the visibility of stripes, we are not necessarily going to have the visibility of a yellow line down the road, and those are the times in which these accidents, in many cases, occur, adverse weather conditions.

Then I look at New York, and I recognize the expertise of your taxi crew there to actually work its way down through a 5th Avenue challenge is something else, and it is something that very few of us in South Dakota get an opportunity to experience, nor want to experience.

So, it would appear to me that what we can do to provide additional data is something that would help everyone, including, and I suspect as Mr. Kildare had indicated, the ability here to provide additional information that is actually beneficial to both the driver and a non-driven vehicle. I am wondering if the focus perhaps shouldn't be more, to start out with, making sure that we have the ability to deliver ongoing data, such as with a stop sign that could be modified. But if

you have a GPS that indicates clearly that there is a stop sign expected at that location, to at least show if there is a difference between what is perceived with the visible perception versus what the GPS should be there would throw out the proverbial red flag.

And then I will shut up. Would you agree with that, Mr. Kildare?

Ms. Trottenberg. I would certainly jump in. From the New York perspective, that data is key. And as you heard from my colleague in Wyoming, New York is also participating in the Connected Vehicle Pilot, and the information that we are gathering is going to be very, very crucial.

That is why we think it is important, as automated vehicle testing goes forward, that jurisdictions, cities and States, that we work out some kind of data sharing arrangement, because that data will be crucial to us in making some of these infrastructure decisions and seeing where there are safety challenges, places we need to improve the efficiency of our roadways.

You know, you are talking about, in a rural context, snow covering up your markings, in an urban context, particularly in a city like New York, we have a ton of infrastructure underneath our streets. On any given day in New York City there are a thousand holes being cut into our streets, so the notion that

our striping will always be pristine and visible, I think it is not likely.

Senator Rounds. Or parked on.

Ms. Trottenberg. Exactly.

Senator Rounds. Thank you.

Thank you, Mr. Chairman.

Senator Barrasso. Well, thank you very, Senator Rounds.

Senator Carper.

STATEMENT OF THE HONORABLE THOMAS R. CARPER, A UNITED STATES
SENATOR FROM THE STATE OF DELAWARE

Senator Carper. Thanks much, Mr. Chairman.

Welcome to all of our witnesses, especially Shailen Bhatt, who used to be our secretary. Shailen, it is great to see you, and thanks for bring your friends with you here today.

I apologize for being late. We all serve on a number of committees and sometimes we just bounce back and forth easily, but we are doing a markup, a business meeting in the Homeland Security Committee today with a big agenda, and we had exactly a quorum; and if I had left, we would have lost the quorum and not been able to proceed, so I appreciate your indulgence here.

I have a short statement I would like to share with all of you.

This important hearing, we are grateful for it, Mr. Chairman. I thank our staffs for the work that has gone into preparing for it.

Harry Truman used to say the only thing new in the world is the history forgot or never learned. Think about that. The only thing new in the world is the history we forgot or never learned.

Today we are here to discuss autonomous vehicles, which do seem like a very new thing, but over 100 years ago, before the advent of driverless cars, the new thing was the horseless

carriage or, as we now call them, cars.

Reflecting on the early history of cars and automobiles, trucks, reflecting on that early history may provide some lessons as we plan for the deployment of today's new technology. I doubt there is anyone here who would deny the tremendous benefits of the development of cars, trucks, vans has had on our society and our economy.

These vehicles connect urban and rural communities; they provide new access to schools, to jobs and hospitals. Cars and trucks have allowed us to travel farther, and to ship and receive goods more quickly and more cheaply.

It is also fair to acknowledge that these mobility improvements have come with some costs. We had to make space in urban areas, often at the expense of existing housing, for better infrastructure in the form of roads and highways. Think I-95 going through Wilmington, for example. Motor vehicles quickly became a major source of emissions and smog, contributing to the threat of climate change, as well as public health crises, such as asthma.

The advent of early automobiles also posed a major safety challenge and infrastructure was required to ensure that they operated more safely. I am told in the first decade of the 20th century there were no stop signs; there were no warning signs; there were no traffic lights; there were no lane lines; there

were no streetlights; there were no brake lights; there were no driver's licenses; no seatbelts; no posted speed limits. None of these traffic controls and safety devices had been developed, so communities were unprepared for this new technology, new vehicles that came along about 100 years ago.

As a result, passengers were at risk. I am told, in 1910, more than 100 years ago, there were 45 deaths for every 100 million miles traveled. Forty-five deaths for every 100 million miles traveled. We have been able to bring that number down to a number just about 1 death per 100 million miles traveled today thanks to a variety of things, but thanks in part to Federal motor vehicle safety standards and investments in safer roadways and safer vehicles.

I think most of us would agree that the number even one, if you happen to be that one, that is one too many. The number is still too high, but in 2016 I am told almost 40,000 people were killed in crashes on our roads across this Country.

I hope that autonomous vehicles will help us reduce fatality rates even further. Over 90 percent of traffic fatalities are the result of driver-related errors, including from drunk, drowsy, or distracted driving. They may be reduced with driverless cars. That would be a good thing.

Indeed, there is no doubt that this emerging technology has the potential to enhance safety, to enhance mobility, reduce

congestion, and improve excess. But realizing these benefits will depend on two important things: number one, how the technology is deployed and also how much we invest to ensure that our streets are ready for this new technology.

One of our major goals should be to avoid the mistakes of the last century, when cars were deployed into our communities without any of the infrastructure standards, the traffic devices, the safety protocols, the environmental protections that we only later realized were essential.

Our hearing today will help us better understand how we can prepare for this transformative technology so that we can realize its many potential benefits, but also minimize the costs associated with cutting corners in our zeal to see this exciting technology deployed.

We need to better understand the readiness of our infrastructure and our traffic controls. For instance, we know that autonomous vehicles can have difficulty navigating certain road conditions, such as poor lighting, such as bad weather, such as work zones. So how do we mitigate with these challenges?

Connected autonomous vehicles may travel more closely together, which could reduce congestion. That would be a good thing. But how will a connected series of heavy trucks affect the weight limits of highway bridges? That could be a dangerous

thing.

Road designs and traffic signs have been optimized for human comprehension; however, we look at the very simple changes that can be made to a stop sign that could interfere with an autonomous vehicle's ability to accurately understand that same sign. I think we have a poster. If you look at the stop sign, with just a couple markings that could be made to the stop sign, it turns into not a stop sign, but a speed limit that says you can go 45 miles per hour through this intersection. That would be scary.

So, we need to ensure that vehicle computers will read signs like that, particularly when graffiti or other modifications can fool an autonomous vehicle into thinking that a stop sign is actually a speed limit sign. We all know, as much as we might hope that something like that is not going to happen, we know that it very well could.

We may need to digitally connect our vehicles to our infrastructure. How much will that cost? How do we ensure that it is compatible with all autonomous vehicle technologies?

Finally, technology is changing at a rapid pace, we know that, but State and local agencies must plan now for transportation investments that won't be made until much further down the road.

How do we align those timeframes and integrate assumptions

about autonomous vehicles into long-range transportation plans?

Those are just a few of the many questions that I believe we need to be examining closely as we prepare our infrastructure for more widespread use of autonomous vehicles.

I look forward to your testimony. Apologize again for being late, but better late than not at all. Now I am here and I am in the game.

Thanks so much, Mr. Chairman.

[The prepared statement of Senator Carper follows:]

Senator Barrasso. Would you like to proceed with questions, or should I go to Senator Capito?

Senator Carper. I would go to Senator Capito.

Senator Barrasso. Senator Capito.

Senator Capito. Thank you. Thank you, Mr. Chairman. And I thank all of you.

Mr. Panos, like West Virginia, Wyoming is a largely rural State with difficult and mountainous terrain. Whenever I hear and think about autonomous vehicles, I think about going up Bridge Road, which is where I live, to my house, and I am like, I am not getting in an autonomous vehicle and doing those curves.

We also have difficulty with in and out of our service, satellite service or internet service. It is very spotty and can be unreliable. In the best case unreliable, and, in the worst case, non-existent.

I understand that in Wyoming your testing is usually in ideal weathers and more flat circumstances, but you are doing some testing in the mountainous regions, so I am interested in knowing how that is going and what type of challenges that presents in terms of autonomous vehicles.

Mr. Panos. Thank you for the question. In Wyoming we are testing not only in open areas, but also in mountainous areas. We have a very diverse terrain. We also have very diverse

weather conditions. So, we are testing the infrastructure equipment not only for its ability to speak with vehicles and for vehicles to speak with it, if you will, but also to test it in terms of its nature as it relates to the various geologic and weather sort of conditions that we have there.

What we have found is, for us, we use DRC-enabled equipment that helps in our communicating with the vehicles. Our focus is on connected vehicles at this point, and connected freight vehicles, specifically.

Senator Capito. So, when you are saying connected, are you saying connected to the device that is on the infrastructure or are you talking about connected in a broadband, wireless way?

Mr. Panos. Well, to use your examples, both.

Senator Capito. Both.

Mr. Panos. They are connected vehicle-to-vehicle and then vehicle-to-infrastructure. And then the infrastructure is connected back to a central location where we actually can send messages to those vehicles --

Senator Capito. So you have to have connectivity.

Mr. Panos. -- and transmit them to others. Excuse me, I apologize. And DSRC helps us to do that, but I think that what we believe will be enhanced is not just the type of technology that we use, because we could use a variety of technology, but really the type of messages and advisories that we are pushing.

Advisories about crashes, advisories about weather that are up in front are the most effective that we can see.

But I must say that this idea of developing a collaboration amongst all of the stakeholders associated with the type and use of technology, whether it be connected vehicle or autonomous vehicle, is the key, and these collaborations, and having Congress support those collaborations, is essential for us as we go forward not just as Wyoming, but as all State DOTs.

Senator Capito. I am also serving on the Commerce Committee. We had a very vigorous debate on AV technology and cars and trucks, and should trucks be included in the first sort of strike that we went in terms of trying to figure out the best regulatory environment to move forward. Trucks were not made a part of that.

I am wondering if any of you all, in your testing or exposure, has been working with large truck vehicles and what you are finding there.

Mr. Panos. I will just mention, if I may, Senator, that that is the focus of our connected vehicle program, is freight specifically, and freight connected not only to the infrastructure and to one another, but freight connected to our emergency response vehicles so that we can reduce the time that an emergency responder can arrive to the scene of an accident or some other type of incident.

Senator Capito. Okay.

Mr. Bhatt. Senator, obviously, the freight component is critical.

Senator Capito. Right.

Mr. Bhatt. One of our members is Peloton that is testing truck platooning, where you use connection between vehicles to reduce the space that is needed, reduce the fuel economy. In places like Wyoming and in Colorado, where you have long distances, it can provide a lot of benefit, safety benefits.

Another issue in Colorado, over Red Mountain Pass, we sometimes have truckers coming into the State that have never been there. There is an issue on I-25. Now they are using their GPS to get around it; they end up on Red Mountain Pass, and Red Mountain Pass there are a couple of curves where, if you don't negotiate them properly, it turns into a pretty significant situation. We are looking at deploying infrastructure-to-vehicle communication so that even if the truck driver isn't aware that it is a safety issue, the truck can be told to slow down to no more than 10 or 15 miles an hour for some of these curves.

Senator Capito. Interesting. Thank you very much.

Senator Barrasso. Thank you, Senator Capito.

Senator Carper.

Senator Carper. Did you go to Ben?

Senator Barrasso. Well, it is your choice. You are first to go with questions, but Senator Cardin would be next in line.

Senator Cardin. Well, thank you. Thank you, Mr. Chairman, and thank you, Senator Carper.

This hearing is extremely important and I thank all of our witnesses.

I have the opportunity to be the Ranking Democrat on the Infrastructure Subcommittee with Senator Inhofe, and as we are looking at the infrastructure authorization for America on transportation, clearly the technology issues need to be part of those conversation, so I think this panel is particularly important. We all support the enhanced use of technology to make transportation more efficient, to make it more friendly, to make it safer.

Certain challenges are brought out by this, and you have already mentioned some. How this comes out of the maintenance budget I thought was an interesting concept, as compared to construction. We don't have enough resources right now into the transportation, so unless we have an adequate funding source, it seems to me that technology is not going to get the attention it needs in the planning of infrastructure.

Secondly, I would point out that technology will help make transportation more efficient, which is what we want it to be, more efficient. But, as we make it more efficient, the revenues

that are coming in to support the infrastructure gets lower, gets less. So, once again, it is so important as we look at developing an infrastructure program for this Country, that we take technology into consideration so that we have adequate resources in order to take advantage of the benefits of technology.

I want to talk about a couple specific issues. I was listening to the messaging boards that you talk about. Very important. If there is a serious issue, motorists need to be advised so they can plan alternative routes, they can plan safety decision-making.

But I find that many of these messaging systems are putting up messages that are not terribly relevant to the driver, but does cause the drivers to slow down, causing congestion and sometimes a safety problem in and of itself.

Is there a protocol as to how these messaging boards are located and whether they should be used indiscriminately or when it is not involving an important message for the driving public?

Mr. Panos. Senator, could I respond to that? Thank you for the question. There is a protocol, actually, that we have developed with the Federal Highway Administration for the siting, construction, and operation of DMS signs, digital messaging signs, throughout our State, and we have internal groups which actually look at the messaging that is going up,

plus we have a 24/7 online traffic management center that actually executes the messages to the signs and makes them as real-time as possible. So, for instance, if we were to have a hail incident that would move through or actually blow through the State from, let's say, west to east, the message signs would change and follow the hail incident as it moves across the interstate highway warning --

Senator Cardin. And that is beneficial. I am for that. But my concern, I will look at my app as to traffic problems on I-95 as I am driving and I will see either yellow or red where the messaging signs are located, and I know the people are slowing down in order to read the messaging signs. Fine if it is important, but if it is not, some of the signs will say have a happy holiday weekend, drive safely, or something like that, which I don't think is worthy of creating a particular problem of a slowdown because people are slowing to read the message signs.

Mr. Panos. Senator, if I may, again, we have a protocol so that we generally would not be putting up non-relevant information on the signs relative to that particular area of the State. Remember, I-80 in our State, where there are a lot of these DMSes, is 400 miles long, so we would put different messages, but also safety messages; and those are the only two things we are allowed to put on the signs based on the protocols

that at least we use in Wyoming.

Senator Cardin. Appreciate it. I want to cover one other subject, if I might, and that is vulnerable populations, bikers, pedestrians. As we develop these new technologies, what protections are there for what this Committee has brought forward under the TAP program to promote pedestrian and bicycle opportunities? If you are now going to have automatic technologies, how do we protect the bikers and walkers?

Ms. Trottenberg. I will take a crack at that, Senator, because I think from the New York City context that is an extremely important question. For our Federal pilot, the Connected Vehicles program, that is one of the issues we are very much looking at; it is not just vehicles talking to infrastructure, it is how can we make roadway safety better for pedestrians, for cyclists. That is part of why we are so interested in having some robust safety protocols as we start the testing. Europe is looking at requiring certain pedestrian and cyclist recognition technologies and why we are interested in having good data sharing, so we can learn what these vehicles are seeing. For us in New York, pedestrian and cyclist safety is a huge, huge priority.

Mr. Kildare. Thank you very much for the opportunity to respond. I think we saw the dangers writ large by what happened with Uber and the crash that occurred. There was mention

earlier about edge cases. The problems we are seeing with AVs at this time are not edge cases. A pedestrian crossing a road at night is not a surprise. A fire truck being stopped on a road is not a surprise. A tractor trailer making a left turn across traffic is not a surprise. These aren't edge cases.

So, we need to collect a lot more of that data. We can do that during testing in controlled ways, but without allowing the system to put people in danger. You can run these systems with a human driver actually doing the driving, collect the data streams, analyze it and see what they are seeing. If we see that the machine would have made the decision to drive towards a bicyclist, we would know that without actually endangering the bicyclist and letting the machine drive towards that bicyclist.

The same thing we saw about the infrastructure problem, what happened with the latest Tesla crash. We would have the data stream saying, hey, the vehicle would have liked to have driven into this roadside hardware, but it didn't because the human driver was always engaged and always doing the driving. So that data is absolutely crucial to collect and have.

Senator Cardin. Thank you all very much. Appreciate it.

Senator Barrasso. Thank you, Senator Cardin.

Senator Booker.

Senator Booker. Thank you very much, Mr. Chairman.

I have a lot of concerns about just the rising levels of

traffic fatalities on our roads. It is stunning to me that we have this kind of carnage. 37,461 people were killed on our Nation's roads in 2016 alone. And we seem to have, maybe popularly, seem to have this resignation that this is just a normal, and it shouldn't be. You know, when you see lives devastated like we have seen in New Jersey very recently, especially with the horrible crash involving a school bus, I think we have to start having more of a conviction to prevent these tragedies from happening.

So emerging sorts of technology is hopeful to me, that there might be a lot of possibilities. Autonomous vehicles present, to me, first and foremost, a chance not to ease congestion; the biggest thing that excites me is the potential to save lives. There are other collateral benefits, reducing emissions. If you live between New York and New Jersey, one side of the river or the other, you understand how traffic is eroding the quality of life of people.

So, I just want to make sure that we are making the kind of investments in our infrastructure that we should be making, and I want to start with Mr. Kildare, which is the greatest name, man, you have, by the way. If I had that name, I would have made it to the NFL in football. The name alone would have gotten me through the combines.

Senator Barrasso. Or he could have been a doctor on

television.

Senator Booker. Exactly. Exactly.

America's roads continue to receive a D from the ASCE, which noted that 20 percent of the Nation's highways alone had poor pavement conditions. The Federal Highway Administration estimates that \$142 billion in capital investment would be needed on an annual basis over the next 20 years to get our conditions to where they should be.

What is, again, compelling me is that, tragically, approximately one-third of road fatalities are caused in part due to deficient infrastructure.

The first question, Mr. Kildare, is whether it is State DOTs, local governments, transit agencies, the whole list of sort of multiple crisscrossing responsibilities, the transportation sector is going to continue to wrestle about how to deal with the new technologies that we are seeing and integrate them in an effective way, and, to make this, capital investments are going to be needed in order to accommodate connected and autonomous vehicles, cars, buses, trucks, and the like.

So, I just want to know what would you recommend in terms of the investment that you think Congress needs not only to accommodate the issues I am talking about, but even just to compete globally to other nations that seem to be making

infrastructure investments much more rapidly than we are?

Mr. Kildare. I believe that the Federal coordination is going to be a critical part to this. A lot of our manuals and a lot of the instruction that we currently have of how we spend our funds and what our designs are are left to the local level, and that is important. It is important because we have the difference between rural and urban and the different experiences that we have.

However, things are going to change as we bring in autonomous vehicles. A tractor trailer trying to find a lane line in Wyoming is the same as the system that is trying to find a lane line in New York City; it needs to know that that is a lane line. You can travel from place to place and see that lanes here are 12-foot wide, this one is 8-foot wide. Lines are 10 foot, they are 15 foot. Everything starts to change because we have allowed this engineering judgment. And it has been critical up to this point, but it is also because they were critical to have the engineering judgment to change based on your area.

When we start having autonomous vehicles, it starts to level that playing field. Finding the right technology and working together so that we know what is the best way we can get each car to know that that is a lane line. What is the best way to get each car to know what stop signs are and not have the

confusion that we saw from the stop signs that Senator Carper had put up. How do we get everyone organized on that so we are making the best investment, especially considering that we need to do both for a long time?

We foresee for a long time coming we are going to have both human drivers and autonomous vehicles, and the last thing we want to do is spend our money heading towards fixing one problem and then creating problems for the other.

Senator Booker. I appreciate that. I want to turn in the seconds I have left, and I see Senator Markey has come, to the DOT Commissioner for, I am sorry, which city is that again?

[Laughter.]

Senator Booker. It sits in the shadow of Newark, New Jersey, I understand that.

[Laughter.]

Senator Booker. It is tough. It is tough. You and Senator Schumer have city envy, I understand.

Senator Cardin asked the question about the challenges as this technology comes in, and the excitement for me about our metropolitan area is tons of new technology could really ease what is an infrastructure crisis that we have in our region. So, I wonder if everything from AVs to, frankly, just drones alone could take a lot of the traffic off of our streets, and in places like New York City, drone technologies might be sort of a

possible help.

I said this to the head of the FAA for a while, I said, look, they were choking sort of the ability for localities to experiment with new technologies and, I felt, overregulating them. France, for example, is doing so much more on drones than we were doing because they had better regulatory structure. And I said, if you guys were around during the time of Wilbur and Orville Wright, we would have never gotten off the ground.

So, I am just wondering, as this person that understands the critical crisis we have. I live 12 miles, 11 miles from Manhattan and it can take me upwards of two hours to traverse that. New Jersey transit and, again, all the work I have been doing on the rail tunnels.

We are just in a crisis proportion. So how are you feeling in the ability to sort of embrace innovation, to create sandboxes for different technologies that you think are critical? And are there things that we can learn from your experiences in one of the most congest metropolitan areas on the planet Earth, the greater Newark metropolitan area?

Ms. Trottenberg. It is great to be in the greater Newark area. You are right, Senator, congestion for us in the entire metropolitan region is a huge, huge challenge. The potential of AVs is that they can reduce congestion, but I can just say right now, I think the New York City experience, and it is probably

true across the river, we are finding services like Uber and Lyft, which say they will eventually be a ridesharing system, right now they are just adding more cars to our streets.

Senator Booker. Yes.

Ms. Trottenberg. And in midtown Manhattan, travel speeds are really slowing, and it is a real challenge. I am actually fortunate right now to be chairing Transcom, which is actually a coalition of New York, New Jersey, and Connecticut transportation and enforcement officials. It was actually the group that got Easy Pass started throughout the region. And we are actually trying, as a region, to look at some of what are these next generations of technologies and bridge one of the challenges we all face, which is how do we bring all our jurisdictions together, New York, New Jersey, the Port Authority, the MTA, New Jersey Transit. Because there is both the technology piece and the jurisdictional and governance piece in making sure, to the extent that we are all pursuing these technologies, they can talk to each other and we can work together.

Drones I think, for New York City, our airspace is pretty dense. I don't know if we are ready to go there, but we are, as we have said here today, doing connected vehicles and starting to look at, again, things we could deploy regionally, because we are one region.

Senator Booker. Yes. And just a question for the record:
Where do the Jets and the Giants play?

Ms. Trottenberg. In the region.

[Laughter.]

Senator Barrasso. Case closed.

Senator Markey.

Senator Markey. Thank you, Mr. Chairman, once again.

Once again, this is an area where Senator Booker and I compete. We compete. I just had him check it out. New York has the second worse congestion and we are number seven in congestion, Boston. One place where we would like to be behind New York in this one category, maybe the only category. And Washington, D.C. is number six.

So, between New York, Boston, and Washington, we have a lot of reason to solve this problem. It is consuming a large percentage of the discretionary time that we have left on the planet, just sitting in vehicles and waiting to get to places, and this new revolution is really computers on wheels, just going down the street. And these computers on wheels could soon be able to send speed and direction data to other vehicles, roads, bridges, other transportation infrastructure, to improve safety, reduce traffic, improve efficiency.

In the very near future we may be spending Federal highway funds to embed sophisticated sensors into our roads and our

bridges, and like the everyday computer and smartphones, these transportation technologies could be vulnerable to cyberattacks if appropriate safeguards are not put in place up front.

Just a few years ago hackers remotely took control of the brakes, steering, and acceleration of a Jeep Cherokee. Chrysler had to recall 1.7 million vehicles to fix this cybersecurity problem. If we are to imagine a world where massive 18-wheelers carrying hazardous materials and minivans full of children can drive themselves, it shouldn't be a stretch of the imagination to envision that these vehicles may be targets of cyberattacks. And unlike many technologies that are already deployed, we have the unique opportunity to address cybersecurity threats before they emerge.

Mr. Kildare, do you believe that we should proactively ensure that robust cybersecurity protections are built into the design, construction, and operation of these transportation technologies?

Mr. Kildare. Absolutely. It is a significant concern. It is also a big concern that we have about the pending legislation, the AV START Act, is that there is no consideration for requirements. I believe the only thing that is in there is a recommendation that companies have a game plan, but not necessarily executed or follow any standards that are available. We have great examples of how this can be done in lots of other

industries. We need to start taking those and learning those lessons from history about how we make these things secure.

Senator Markey. Beautiful. I agree with that, and that is why I have introduced legislation with Senator Blumenthal, the SPY Car Act, that directs NHTSA to establish Federal standards to secure our cars.

Mr. Kildare, do you believe that it would be helpful if NHTSA, the National Highway Traffic Safety Administration, created a cybersecurity certification program for vehicles, similar to NHTSA's five-star automobile safety rating program? The program would reward manufacturers who adopt the strongest protections, while also helping consumers make more informed decisions when purchasing or riding in vehicles.

Mr. Kildare. Absolutely. I believe the benefits that we have seen from the NHTSA five-star program have shown how we can encourage competition in the goal of getting safety out the forefront. The same thing can be done with the cyber dashboard and looking at cybersecurity. We always want to see it move towards regulation at the end, and we have seen that happen out of the five-star program as well, so it is an excellent need.

Senator Markey. Now consumers say, oh, how many miles per gallon? We can see that. What is the safety rating? They can see that. And, going forward, this cybersecurity protection is also going to be increasingly important because it is a computer

riding down the street, and there is a sinister side to cyberspace. It is the best of technologies and the worst of technologies simultaneously. There is a Dickensian quality to it; it can enable, it can ennoble, it can degrade, it can debase. We just saw that in the Facebook hearing. We continue to see it. If we don't protect against the downside, then bad things happen, so it is important for us to build in the cybersecurity protections now.

Finally, the only thing more quintessentially Boston than cold weather and the Boston Red Sox is traffic. But technology could help address traffic issues by allowing communities to more accurately and comprehensively monitor traffic patterns and then take preventative measures, rather than reactionary measures, to alleviate congestion.

How can these sophisticated transportation technologies help us be more efficiently traveling, especially in the densely populated urban areas of the Country?

Ms. Trottenberg. I guess I will speak for densely populated urban areas. I think, again, sort of speaking of the Dickensian nature of these potential technologies, as you have heard, they can potentially enable vehicles to travel together more closely, to anticipate obstacles in the roadways, reduce crashes and accidents, which obviously has a big effect on moving traffic.

I think it is certainly true in the metropolitan region of New York, and Boston as well. I just have to sort of have to make a pitch, I guess, for a different committee's jurisdiction. For us in the end, the biggest thing that is going to help us probably solve our congestion problems is going to also be robust investments in our mass transit system. The efficiency of what a train can carry, even versus a platooning set of vehicles, there is no comparison; the mass transit system is always going to be the workhorse for New York in terms of carrying the population.

Senator Markey. Thank you, Mr. Chairman.

Senator Barrasso. Thank you, Senator Markey.

I was just talking with the good Senator about he was too young to remember the doctor show that we grew up with, Dr. Kildare.

Senator Carper. Dr. Kildare, Ben Casey, Dr. Casey. There were a bunch of them.

Senator Barrasso. There was Ben Casey, there was Dr. Kildare, there was Marcus Welby, MD. That is why I became a doctor.

[Laughter.]

Senator Markey. If I may add, that is why my wife became a doctor, looking at Dr. Kildare. And the beginning of the show is the front of Massachusetts General Hospital in Boston,

Massachusetts. All politics are local.

[Laughter.]

Senator Markey. The inspiration came out of that location.

Thank you.

Senator Carper. I know his wife. My wife and I are good friends, and his wife is an inspiration.

The Chairman and I were talking just a little bit. I have some prepared questions, but one that is just audible here, he represents a big State and a lot of roads, and a lot of those roads in his State are dirt roads or gravel roads.

As Chairman Bhatt may recall as Secretary of Transportation in Delaware, we used to have a whole lot of dirt roads and gravel roads. We don't have quite as many anymore, but we have a lot of roads in the more rural parts of our State that are not marked. We still have some dirt roads and some gravel roads, but there are a lot of places across the Country that are more like not just the town of Wyoming, Delaware, but are more like the State of Wyoming, where they have a lot of dirt roads and gravel roads.

How do we handle that? How do we stripe them and get ready for just minor, inexpensive infrastructure enhancements that will help make autonomous vehicles work in those areas? How does that work?

Mr. Bhatt. So, that is a great point to make, Senator

Carper, and a great question. One of the things that I know Colorado DOT is taking a look at as a research program now, working with other partners, SAE classifies autonomous vehicles Level 1 through 5 based on their ability to either be driven or self-driven.

What Colorado DOT has begun looking at, or the RoadX program, is a roadway classification system. So, we will have interstates that have great pavement and markings and signage and connectivity, all the way down to a rural dirt road that may not even have cellular coverage. Much like when you used to buy a cellphone, you were provided a map around where that cellphone could work, I think there will be part of our network that will never have those levels of connectivity, and it will be up to, as Commissioner Trottenberg said, the manufacturers to make sure that their vehicles are able to drive on a vast majority of our system.

Senator Carper. But, as we all know, there are a lot of times when we go around States around the Country, we try to use our cellphones and they don't work. I know a lot of people with autonomous vehicles say, well, I will take a chance, maybe it will work today.

All right, thank you. That is interesting.

Okay, a question, if I could, for Polly Trottenberg. How are you today? Very nice to see you.

Have auto manufacturers and software developers shared information with you about their technologies' reliance on infrastructure in order to safely navigate public roads? This information seems like it would be vital to the public agencies who own and operate our transportation infrastructure when setting standards and shaping the deployment of autonomous vehicles to ensure both safety and compatibility.

I guess specifically do you think that access to safety evaluation reports would better equip our public agencies in their efforts to set appropriate standards for autonomous vehicles?

Ms. Trottenberg. Absolutely, Senator. We think that is crucial. I think Mr. Kildare put it well.

Senator Carper. Dr. Kildare?

Ms. Trottenberg. Dr. Kildare. It is essential for us, as he was saying, as these vehicles hit the roads and start doing their testing, to know where they had near misses, where they might have interacted with a pedestrian or cyclist. It is important for us to get the sense of their safety operations, but, again, it will help us as well, it will help us look at our infrastructure. It is really valuable data.

Certainly, I think something to be very thoughtful of as you are regulating at the Federal level and at the State level, for a city like New York, which is such a big and unique entity

in and of itself, we really want to make sure that we have a seat at the table and that we can be part of understanding that data and very sensitive to protecting it and the proprietary nature of it. But it is really key for us, in our dense urban environment, to understand how these safety systems work and what they are seeing if they hit our roadways.

Mr. Doerzaph. I will add a little to that, too. One of the neat things about these new vehicles is they come with a plethora of sensors that provide very direct information about what it is in the infrastructure that creates a difficulty for them, which can help an operator really prioritize how they spend those public dollars by focusing on the elements. It may be as simple as a reflection off of a particular bridge that radar over-responds to. So, having not just general feedback to where incidents are, but details about what it is that is fouling up a particular sensing or perception system is new and also potentially very valuable.

Senator Carper. All right, thank you.

Mr. Panos, you have been before us before; so has Shailen, as have one or two others before us today. Are you a director of the Department of Transportation? Is it director, secretary, commissioner? What is it?

Mr. Panos. Director of the Department of Transportation.

Senator Carper. All right. I want to start out with a

question for the whole panel, but I will just start off with you, if I could.

Recent studies from the University of Michigan and Ford Motor Company suggests that adding AV equipment to cars adds weight, aerodynamic drag, and electrical power consumption that internally increase to fuel consumption. Because AVs could both reduce the cost and increase the availability of driving that could induce greater demand and increased vehicle usage, we may have more vehicles on our roads. We talked about that earlier. Empty vehicles circling city blocks and riders opting for longer commutes.

With on-road mobile source emissions already the largest source of greenhouse gas emissions, in our economy, are you concerned that widespread autonomous vehicle deployment may actually worsen this problem? Would you agree that we need more data about how these vehicles will be used in the real world to better inform our understanding of the role that autonomous vehicles will play in transportation sector greenhouse gas emissions?

Mr. Panos. With regards to the idea that we need more research dollars and more focus on deployment of connected and autonomous vehicles throughout the United States and the various environments, some of them represented by some of my colleagues here today, I would say yes, that we do need to invest more

research dollars, and already have. The collaborations between the USDOT and AASHTO, the collaborations between the industry and government have been robust, but need to continue. And the investments in infrastructure research for connected and autonomous vehicles need to continue.

Senator Carper. All right.

Shailen?

Mr. Bhatt. Senator, I began my career trying to reduce single occupant vehicle trips, trying to get people into high occupancy vehicles. The idea that we would have zero occupancy vehicle trips with fleets of autonomous vehicles circling without anybody in them is antithetical to intelligent mobility, so I think we would want to make sure, in working with States and local partners, to make sure that that was not an outcome that we got.

And your point, I think, is well taken on the increased fuel consumption. We haven't spoken as much about it today, but I think a great belief, at least globally, is that the future of mobility also includes a great deal of electrification of the fleet, and that will be something that will help with some of the emission issues.

Senator Carper. That is a good point. Good point. Thank you.

Is it Dr. Doerzaph? Thank you. Same question.

Mr. Doerzaph. I am going to echo what both of them said. Some of that is also a sign, I think, of the current maturity of the industry. Sensor racks are hanging off the cars because we are taking legacy cars and retrofitting them. As we move towards vehicles which are designed for automation, some of the aerodynamic drag aspects will fall away. Some of the weight will probably fall away, as well, as those systems are optimized.

And then, mostly, I would just echo that, yes, zero passenger vehicles should be minimized. If we are going to really have a profound impact on congestion, we need to double or triple or better on every vehicle.

Senator Carper. All right, thanks.

Commissioner Trottenberg.

Ms. Trottenberg. I think you have --

Senator Carper. Was Iris Schumer commissioner?

Ms. Trottenberg. Yes, it was Iris.

Senator Carper. During the Blumberg administration?

Ms. Trottenberg. She was Giuliani and Blumberg.

Senator Carper. Okay.

Ms. Trottenberg. You have asked the key question. Today we are focusing so much, first and foremost, understandably, on is the technology safe, how do we ensure it is safe, but you are really getting to what I think, in urban areas, is the key

public policy question. If we deploy this safe technology and all it does is further congest our streets, I think this will not have been a very successful program.

I think it does bring a lot of policy considerations in, and ones that I will again just make a pitch, localities really need to be part of that process. In New York, we are now seeing Ubers and Lyfts are congesting our streets. They are not no occupant vehicles, but they are one occupant vehicles spending a lot of time cruising in our central business district.

So, we need to both get the technology safe and then grapple with the key public policy parts of this. If we are just adding to the congestion and fuel consumption and emissions, then this technology won't have realized its potential.

Senator Carper. All right, thank you.

Dr. Kildare.

Mr. Kildare. Thank you for the question. I believe this actually highlights what everyone has been saying here, that there are a lot of questions around these vehicles and what the implications are going to be, and that is one of Advocates' big points about the issues with the AV START Act, that there is a push towards deregulation and towards preempting some of the States from controlling what is going on with the lack of Federal leadership, a lack of leadership from NHTSA.

We need that coordination between NHTSA and Federal Highway, and we need to be moving towards regulation, not away from it, to making sure that we are going to get the proper results that we are looking for and not have these unintended results that could then compound and cost billions of dollars when it comes to infrastructure improvements that we need to address the problems that are now created.

Senator Carper. Mr. Chairman, I have two more questions that are fairly short.

A question, if I could, for Dr. Doerzaph. One of the risks that connectivity introduces, the ability to spoof, we talked about this a little bit earlier, spoof, to hack or trick vehicles into behaving in ways they should not, the stop sign into 45-mile speed limit sign, such as believing a red light is green or a stop sign is a speed limit sign. Research news stories in the California Disengagement Reports have been useful to identify the trouble that automated vehicles have with consistently and correctly identifying traffic lights, bicycles, bridges, pedestrians, animals, and other vehicles.

Given how difficult it is to already maintain our physical infrastructure free of defects, do you believe that we can develop a nationwide physical and digital infrastructure that will be pretty much foolproof, to the point that we can and will safely rely on it?

Mr. Doerzaph. That is a great question. It gets back to the security by design question that we were talking about earlier, so starting that conversation now and baking it into every aspect of those systems is critical.

I think it is also really important to realize or to think through that, yes, any one subsystem can have a failure, much like humans do. We may see an illusion or hear something that is not actually there, or misrepresent a threat. AV is subject to very similar set of conditions. They are slightly different because their sensors are different, but one of the advantages of AV is that we can have many more sensors.

So, the sensor fusion aspect, where, yes, the vision system sees a sign that is inappropriate, well, that is okay, the mapping system knows the correct. And, by the way, it is not just the maps, two maps, it is a local one that is stored and is known to be highly secured, and it has been confirmed by a recently updated map as well.

So, really, the security is multifaceted. There is the aspects of the security which are keeping bad actors from tampering with the systems, but also the aspect of ensuring that what is being perceived by a sensor external to the vehicle is being confirmed by multiple subsystems as well.

So, if that design is appropriately managed, as the evolution occurs, I think it is reasonable to reach a secure

system. At the same time, we need to be mindful that the population of hackers and whatnot are bright and they move with the times as well, so we need to be able to identify those bad actors and successfully remove them from the trust network, which, again, requires a very robust, nationally synchronized, security mechanism.

Senator Carper. All right, thanks.

Last question I would start with Secretary Bhatt. I don't know if anyone else would like to comment on this question, but if you want to, you are welcome to do that.

The solvency of the Nation's Highway Trust Fund is, as you know, a top concern for our Committee. What are the budgetary implications of enhanced deployment of autonomous vehicles on public roadways and the cost to enable infrastructure to be digitally connected? Are these costs likely to exacerbate the funding challenges that we face already in public agencies on this front? On the flip side, is there a new opportunity to collect mileage-based user fees on vehicles that are digitally connected to the infrastructure that they are using?

Mr. Bhatt. Senator, thank you for that question. I think that you raise a couple of very important issues. As Director Panos has mentioned, most of the striping and signage that is critical for the operation of connected autonomous vehicles as we move forward comes out of maintenance budgets, and if you are

going to increase your maintenance budget, that is going to obviously impact your construction budget.

And as Commissioner Trottenberg mentioned earlier, the manufacturers need to make sure that they are factoring in the fact that many roads won't be able to be upgraded, given the budget challenges. So, I think that we need to make sure that we invest in technology and in infrastructure, because I think that technology can be used to leverage infrastructure to get more productivity for our economy. I think of it as a global economic competitiveness issue.

I also believe that there has been a lot of discussion over the years, you have led many of the discussions around funding and gas tax issues. Outside of that, I think that the new technology is the best way for us to move to whatever will succeed the gas tax, whether it is a mileage-based user fee or VMT or road usage charge, because I think we now have the technology piece that can both be secure and delay some privacy concerns that have been out there, and those are the discussions we need to begin with now.

Senator Barrasso. Thank you, Senator Carper.

One quick question for Mr. Kildare. Mr. Doerzaph talks about this plethora of sensors that are available, and I think you had talked about the idea of individuals have to go and get an eye exam at the Department of Motor Vehicles, and should each

vehicle would independently have to go and get examined to make sure all the sensors are working right, or is it something that would be part of the patenting process when they design that? I am trying to figure out how that all plays into what we are looking at.

Mr. Kildare. Using the term loosely for AV vision test is establishing requirements for what vehicles need to be able to see and respond to, that we need to design, if we take what we see at the FAA as an example, and we look at either safety the intended function or we look at functional safety, your product needs to do the things it says it can do and it needs to not do the things it says it can't do. And making sure that vehicles aren't operated outside of those envelopes are very important.

We had the mention about the sensor fusion, getting sensors to work together. The first part will be can your sensors see that stop sign. Does it know that it is a stop sign? Does it know that it is a stop sign when it has been molested in some way, either in terms of graffiti or art work or bent or -- I have been through Texas -- shot at? They are used for target practice. There are a lot of changes that can happen out there. We need to establish what are the requirements for whatever that operation is going to be.

We know in the Tesla crash down in Florida, that that vehicle was not supposed to be operating under autopilot on that

road, but it was. So how do we do that? What are the requirements we need to establish? If you tell us your vehicle operates only on highways, how do you prove that that vehicle only operates on highways? The same thing for the vision. What does it need to see?

The vision test that we have implies some responsibility on the part of the driver. We ask people to identify a stop sign because they have to stop the vehicle. Now that we are testing the machine, it has to see the stop sign at all times and it has to decide to stop the vehicle. That is what we have to require. That is the concern that we have with what we are seeing in the AV START Act, is that we don't see any of these requirements coming up, and we need them.

Senator Barrasso. I appreciate it.

I appreciate the panel and all your thoughts.

Senator Carper, if you read broadly on this, the technology of where this may go to the issue of these driverless cars circling or do they go someplace else, if they go someplace else, people write about eliminating many parking lots and having an opportunity for actually more buildings in communities.

What does it change in the real estate markets? An article in the Economist this week, under Free Exchange, called "Road Hogs," says economies of scale will push the market for

driverless vehicles towards a monopoly.

There are many different components of all of this. They are talking about car dealers no longer going to sell to an individual, but to a fleet, and how does this change the number of vehicles on the market.

I don't know that any of us, if you read enough and different futurists who look at this, it doesn't seem to be that there is a uniform agreement as to where the future may be taking us as this all plays out in time, so I am just very grateful that all of you would take your time today to come here to testify from a variety of backgrounds, but to give us your very best thoughts. I thought it was a very helpful hearing and I appreciate all of you.

The hearing record is going to remain open for a couple more weeks, actually two weeks, so some other members who have been here and haven't had a chance to ask questions may submit written questions to you, so I want to thank you again for your testimony today on this very important issue.

With that, the hearing is adjourned.

[Whereupon, at 11:39 a.m. the committee was adjourned.]